

Pavillion Oil & Gas Field Pits Evaluation

U.S. Environmental Protection Agency Region 8

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Introduction and Purpose of EPA's Evaluation

The Environmental Protection Agency (EPA) Region 8 has evaluated available information on the presence and remediation status of historic production pits in the Pavillion gas field near Pavillion, Wyoming. The EPA is providing this evaluation as technical input to stakeholders participating in the pits work group and for consideration in the development of the pits study. Consistent with the joint involvement by the EPA, State and Tribal governments regarding Pavillion groundwater issues, EPA will continue to consult and coordinate with the Northern Arapaho and Eastern Shoshone Tribes of the Wind River Indian Reservation regarding this document to further the protection of the environment and human health. EPA's transmittal of this document is intended to convey our technical considerations only, and should not be construed as setting forth any position regarding the exterior boundaries of the Reservation or the exercise of State authorities in this area. The objectives of this evaluation were to summarize existing information to:

- Describe the universe of pits in the Pavillion gas field and the efforts of the pits work group to ensure that universe includes all known pits;
- Discuss cleanup standards and processes that have been applied in efforts to remediate pit concerns; and
- Describe EPA concerns with existing remediation approaches and cleanup standards from a potential health risk perspective.

Background Information Regarding Pits in the Pavillion Field

Closure Requirements

The current operator in the Pavillion gas field, Encana, has for a number of years been engaged in efforts to identify and remediate concerns with historic production pits constructed and utilized by prior owners of the field. The three agencies involved in oversight of pit closure in the Pavillion field are the Wyoming Oil and Gas Conservation Commission (WOGCC), Bureau of Land Management (BLM) and the Wyoming Department of Environmental Quality (DEQ). According to a BLM Instruction Memorandum, BLM regulatory closure cleanup requirements are typically determined using the same approach as WOGCC.

The closure process for pits in the Pavillion field varied based on the procedures and protocols under which the pit was undergoing closure. A brief description of the closure procedures, as EPA understands them, is presented below.

WOGCC Closure Process and Criteria

For all investigated pit sites, Encana used WOGCC's Oil Contaminated Soil Remediation Ranking System (OCSRRS) to calculate a pit-specific Total Petroleum Hydrocarbon (TPH) cleanup level at each site. The OCSRRS is described in more detail below. The WOGCC process also includes limitations in Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR) to preserve plant life and prevent negative impacts to plant growth within the historic pit location. The ESP cleanup standard for all areas throughout the state is

15%, and the SAR cleanup standard is 12. (Wyoming Oil and Gas Conservation Commission, 2002)

Encana investigated each pit site by collecting soil samples within the pit locations (assisted by aerial photography or plat map, if one existed) and compared the soil analytical results to the cleanup level. If analytical results for TPH, ESP and SAR from the initial soil borings were lower than the target cleanup levels, no further investigation or remediation was performed. If the soil results were higher than the target cleanup level, Encana excavated soil until analytical results from the four walls and floor of the excavated area were below the TPH cleanup level and within acceptable limits for ESP and SAR. At that point, if the excavated area had not reached the water table, the excavation was concluded, the pit was backfilled and the remediation was considered complete. However, if the water table was encountered, the groundwater was sampled, and if groundwater was contaminated in excess of State standards, Encana sought enrollment of the pit site into the DEQ's Voluntary Remediation Program (VRP). Encana enrolled a total of 4 pit sites in the VRP, 3 based on initial investigations and a fourth that was added later in the process.

OIL CONTAMINATED SOIL REMEDIATION RANKING SYSTEM (OCSRRS)

The OCSRRS utilizes a ranking system to evaluate the environmental sensitivity of a site. A site is scored in various categories related to environmental threats and sensitivities. The category scores are added together to give an overall score. The overall score determines the TPH cleanup goal for the site. According to the guidelines document, the OCSRRS was developed through long practice of WOGCC staff.

- Categories included in OCSRRS (and highest potential point value from each category): Distance from bottom of the contamination to the aquifer (0-20), Aquifer Water Quality (0-10), Distance to surface water (0-20), Soil Medium/Permeability (0-20), Distance to Water Wells (0-15), Distance to Public Areas and Residences (0-10), Annual Precipitation (0-20), Irrigated Crop Land (0-20), Oil API Gravity (0-20)
- Final score ranges from 0-155. The final score correlates to cleanup goals that range from 1,000 to 10,000 mg/kg TPH soil concentration. A site score of 90 points or greater requires cleanup to the most stringent cleanup level of 1,000 mg/kg TPH.
- The OCSRRS site score is calculated and documented by the operator.

The OCSRRS is described within the "Guideline for Closure of Unlined Production Pits" document (Wyoming Oil and Gas Conservation Commission, 2002). Other points from this guidance document include:

- Fresh and potable water is defined as water currently being used as a drinking water source or having a TDS concentration of less than 10,000 milligrams per liter (mg/l) and which can reasonably be expected to be used for domestic, agricultural, or livestock use. In general terms, TDS concentration limits for domestic use are 500mg/l, for livestock are 5,000 mg/l, for agricultural use are 2,000 mg/l. It should be noted that areas in Wyoming currently use water with quality poorer than these general limits.

- Hydrocarbon contamination and dissolved solids, or salt contamination are the two potential types of contamination identified. TPH testing is required for all sites; however, according to the guidance, testing for benzene and polycyclic aromatic hydrocarbons (PAHs) using EPA Method 8260 and PAH using EPA method 8270 can be required when the Commission deems appropriate.
- From the guidance, it is clear that "closure standards and testing requirements for all pits will be determined by the Supervisor based on site specific conditions." It is not clear to EPA what conditions would be necessary to require more rigorous closure standards or testing requirements.
- Chapter 4, Section 1(v) allows up to 10,000 mg/kg, or 1% by mass, TPH in noncritical areas where there is presumed to be no probability of contamination of an aquifer. The guidance indicates it is anticipated that the majority of production sites will be in noncritical areas.
- A ranking system for salt contamination cleanup levels has not been developed. The cleanup standards for areas within the plant root zone (top 3-4 feet) are an Exchangeable Sodium Percentage (ESP) of less than 15% and a Sodium Adsorption Ratio (SAR) of less than 12. EPA is currently reviewing the scientific literature, in collaboration with the U.S. Department of Agriculture, to evaluate surface water quality criteria for SAR that would be protective of soils in agricultural production. The results of this review could be informative regarding soils clean-up levels that would be protective of agriculture.
- The Guidance indicates further testing of wastes and additional disposal requirements prior to closure of a pit may be appropriate if there is reason to believe extensive subsurface contamination or groundwater contamination is present.

DEQ VRP Process and Criteria

If a pit was the source of groundwater contamination above State groundwater quality standards, Encana sought to have the site enrolled in the VRP. Encana has requested enrollment of four pits (42-11, 14-11, and 24-03 in 2008 and Blankenship 4-8 in 2011) in the VRP.

VRP guidance fact sheets describe a process to determine the presence and extent of pit contamination impacting groundwater. The VRP process provides for public participation. Responsible parties for sites seeking VRP status provide written notice and an opportunity for public comment when the site is originally enrolled in the program as well as when the remedy is selected. (Wyoming Department of Environmental Quality, 2011)

During a typical VRP process, the VRP site owner completes a site characterization in order to develop a conceptual site model. The site characterization should describe the site setting, known and potential sources of contamination, the nature and distribution of contaminants and media properties that are likely to influence contaminant distribution, and human and/or ecological receptors. The adequacy of the site characterization is evaluated using the site characterization performance criteria which are drawn from the VRP cleanup standards and

established engineering and geologic practices. (Wyoming Department of Environmental Quality, 2012a)

According to VRP fact sheets, the cleanup standards approved by the VRP must: protect human health, safety and the environment; remediate contaminated media to attain applicable standards, or to attain site-specific, risk-based levels developed for the site; control any sources of releases to reduce or eliminate, to the extent technically practicable, further releases; and comply with any applicable standard for management of wastes generated as a consequence of the remedy. Under the VRP, site-specific, risk-based cleanup levels are to reduce excess cumulative cancer risk to between 10^{-4} and 10^{-6} , with 10^{-6} level used as a target risk level. Additionally, non-carcinogenic contaminants cannot exceed a cumulative hazard quotient of one. (Wyoming Department of Environmental Quality, 2012b) This risk-based approach points to the need for consideration of a sufficiently broad range of analytes at detection limits low enough to compare against risk thresholds in order to comprehensively assess whether these risk goals are being met.

VRP Soil Cleanup Fact Sheet and Contaminated Soil Cleanup Level Table

The VRP has a fact sheet which discusses a method to evaluate whether soil contamination is present at a level that may require further evaluation and/or remediation. (Wyoming Department of Environmental Quality, 2012c) There are two bases for cleanup levels presented in the corresponding cleanup level table: direct human contact and migration to groundwater. (Wyoming Department of Environmental Quality, 2009) The migration to groundwater pathway is the pathway of concern in Pavillion as the pits are covered with backfilled material limiting direct human exposure. The concentrations presented in the table are soil cleanup level comparison values that are considered protective against contaminant migration to groundwater. These concentrations are based on an assumption that a certain amount of the chemical will infiltrate through soil to the underlying groundwater. Soil concentrations are based on groundwater ingestion risk values and then back-calculated to a soil concentration of concern. In other words, soil screening concentrations correlate to target risk levels of potential groundwater contamination.

The derivation of soil screening concentrations assumes no reduction of soil leachate concentration from mixing in an aquifer and no reduction from attenuation as leachate moves down through soil to the groundwater table. It is important to note that contaminant concentrations higher than the table levels do not necessarily mean remediation is necessary. It does mean further site-specific assessment should be completed.

The values presented in the cleanup level table have been derived using methodology similar to EPA's Regional Screening Levels (RSLs), Soil Screening Levels (SSL) for the Protection of Groundwater, which are discussed later. The same assumptions are used to derive both VRP soil clean up levels and EPA SSLs. The only difference appears to be that EPA regularly updates the RSLs semiannually, whereas the DEQ VRP soil clean up levels appear to have remained the same since 2009.

The VRP table provides risk-based screening levels (1×10^{-6} target cancer risk and target noncancer hazard quotient of 1 for single chemical exposures) that are to be applied to all sites entered into the VRP program. These values are created based on an assumption that there are relatively few contaminants present. However, exposure to multiple chemicals would create potential additive health effects that are not accounted for. Since this is likely the case with production pits due to the numerous contaminants detected, cleanup goals may need to be lower than the values listed to achieve comparable risk reductions. In situations where the contaminants are few in number, these values represent conservative concentrations that, if met, will likely be protective regardless of location and future use.

The VRP Contaminated Soil Cleanup Level Table is included as Appendix A. The soil cleanup levels presented in the VRP Contaminated Soil Cleanup Level Table for soil migration to groundwater for select target chemicals are as follows:

Benzene	0.00023 mg/kg
Toluene	1.7 mg/kg
Ethylbenzene	0.0019 mg/kg
Xylenes	0.23 mg/kg
Naphthalene	0.00055 mg/kg
Benzo(a)pyrene	0.0046 mg/kg

VRP Fact Sheet Discussion of Hydrocarbon Stained Soil Cleanup

The VRP has derived cleanup levels for Gasoline Range Organics (GRO) and Diesel Range Organics (DRO).

TPH Gasoline and Condensate Range Organics	28 mg/kg
TPH Diesel Range Organics	2300 mg/kg

The GRO cleanup level for soil may depend on two site specific parameters: depth to seasonal high groundwater table and thickness (depth) of the contaminated soil. The DRO cleanup level for soil is derived for an oral ingestion exposure pathway, as it is a more protective clean up level. The fact sheet discusses the applicability of the VRP DRO and GRO cleanup levels. The fact sheet acknowledges that these cleanup targets do not apply to pits closed using the WOGCC process. (Wyoming Department of Environmental Quality, 2012c)

Universe of Pit Sites in the Pavillion Field

The Pavillion pits workgroup attempted to determine the universe of historic pits in the Pavillion field that were used to store drilling fluids, production fluids, etc. prior to the operator's use of storage tanks for these materials beginning in the mid-90s. According to Encana, the current operator in the Pavillion field, neither the previous operator nor Encana drilled and operated new wells using reserve or production pits. In lieu of pits, produced material was stored in tanks since work began at the site. Of the approximately 145 gas wells in the Pavillion field (not including plugged and abandoned wells), a total of 51 potential pit sites were reviewed by the workgroup as part of the workgroup process.

Sources of Sites

In 2005, Encana began investigating pit sites in the Pavillion field. Using historical aerial images and site files, Encana initially investigated 26 pit sites in the Pavillion field and 2 pit sites in the Muddy Ridge field. At least one additional site (Blankenship 4-8) was planned for investigation but Encana was apparently not provided access for an initial investigation. This site was evaluated at a later date, bringing the total pit sites evaluated using OGCC guidance to 29 sites. Encana has enrolled 4 of these 29 sites in the VRP. These 29 sites are included in a table below.

To attempt to ensure that the full universe of pits was understood, the workgroup requested that landowners provide input regarding other locations of pits they would like to have investigated. Pavillion residents compiled a list of these Community Identified Areas, which included 22 other potential pits (as well as 10 pit sites which had previously been evaluated by Encana using OGCC guidance) in addition to the 29 already identified by Encana and WOGCC. Pavillion Area Concerned Citizens sent a handwritten list of these 32 potential pit sites to EPA in January 2011. On April 13 and 14, 2011, pits work group members Rob Parker (EPA), Tom Kropatsch (WOGCC), Kathy Brown (DEQ), Kirsten Derr and Andrea Taylor (Encana), and John Fenton (landowner) conducted site visits at all of the Community Identified Areas.

Including the 29 Encana previously evaluated pits and the 22 additional community identified areas, a total of 51 potential pit sites were reviewed.

Types of Sites

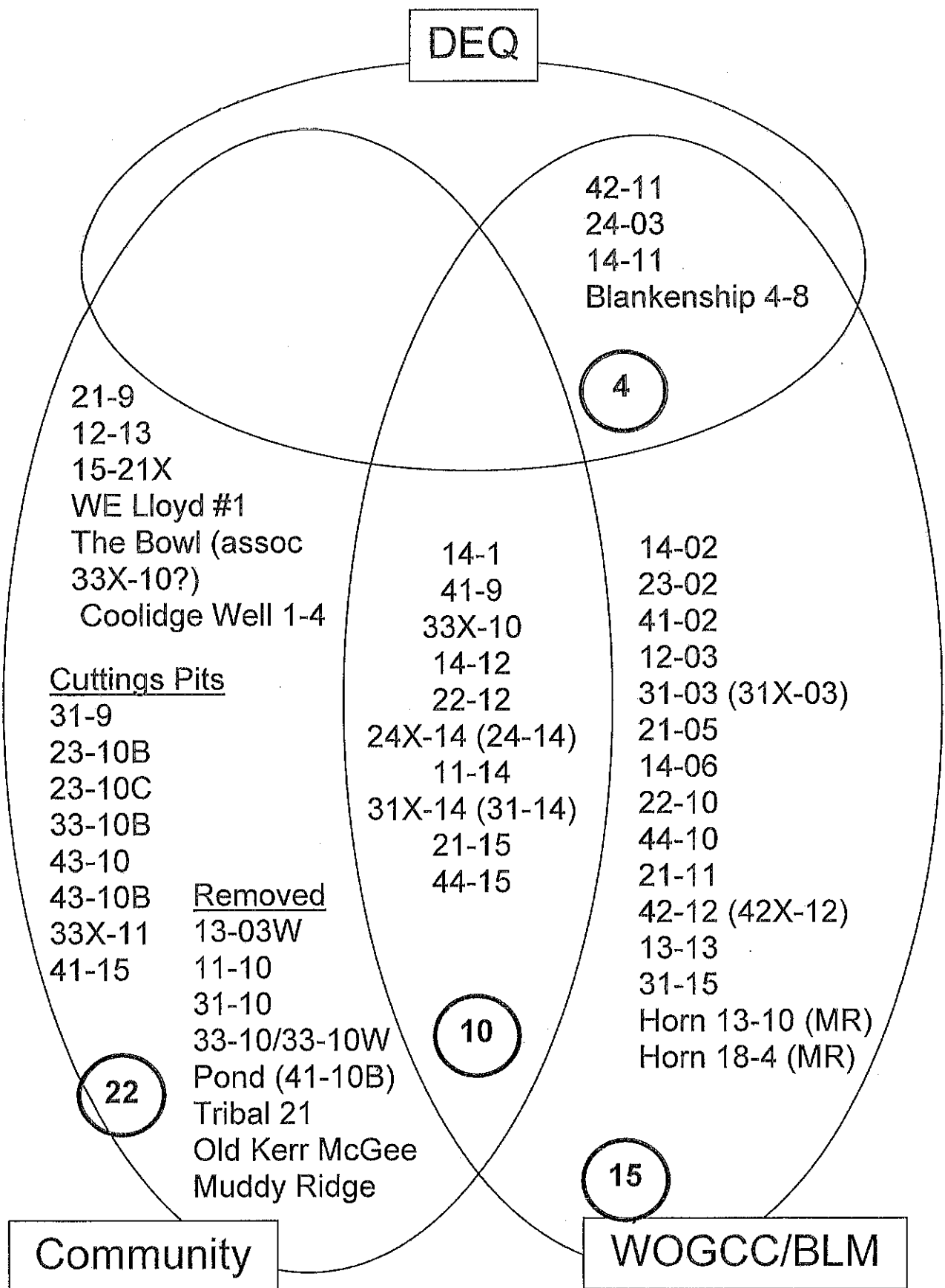
Of the 51 potential pit sites:

- Four sites have been enrolled in the VRP, since these sites had known groundwater impacted above State standards. These four sites have undergone some level of site characterization by Encana in an effort to develop a Remedial Alternatives Evaluation (RAE) report.
- Eight community identified area sites were removed from consideration due to the conclusion that no pit was located at the site (based on file and field review). These are titled 'Removed' in the diagram below.
- Twenty-five sites were evaluated using the WOGCC process, including two in the Muddy Ridge field.
- Eight cuttings pits identified by the community were separated due to lower TPH concentrations that have generally been associated with cuttings pits. These are titled

'Cuttings' in the diagram below. The workgroup designated these sites as low priority for further action.

- Six other sites were identified by the community. These include a site with 3rd party ownership (therefore, not investigated by Encana), a site with no documentation of ownership, and 4 sites with other pits not investigated.

The universe of pit sites reviewed by the workgroup is characterized below in a Venn diagram.



Data Captured from Previous Activities

Pits closed by EnCana using WOGCC process

According to Encana, twenty-eight sites were originally investigated using the WOGCC process described previously. One additional site has since been investigated that was intended to have been investigated previously, but was not due to access issues with the landowner. A spreadsheet compiled by WOGCC is presented below (see Table 1). The spreadsheet contains the TPH cleanup goals and pre (if no remediation was required) or post-remediation TPH concentrations (in mg/kg TPH) for each site.

As can be seen below, some sites that exceeded the clean-up goal and subsequently underwent remediation do not appear to have final soil investigation reports. This may indicate the need for additional documentation of soil sampling that was conducted post-remediation, or for post-remediation sampling where that has not been completed.

Table 1

Well Name	API No.	Qtr Qtr	Section	Township	Range	Soil Remediation?	Pre-Remediation TPH Concentration (mg/kg)	Cleanup Goal (TPH mg/kg)	Post Remediation TPH Concentration (mg/kg)	Metals Analysis (Y/N)	List of Metals > Concentration Thresholds	WOGCC Comments
TP 14-01	1306389	SWSW	1	3	2	y	4890	2500		y	None	Cleanup goal stated in report varies 2,500 in pre-remediation table but 4,000 in post-remediation table? Re-scored. WOGCC agrees w/4000 but site is Tribal, BLM must set limit
TP 14-02	1321128	SWSW	2	3	2	y	Unknown	1000	900	N	None	based on report it appears excavation was conducted during original site investigation but it is difficult to determine how much material was removed appears approx. 50 yds3, all samples met cleanup level
TP 23-02	1306395	NESW	2	3	2	N	NO (<14)	1000		y	None	Full report doesn't appear to have been provided?
TP 41-02	1320454	NENE	2	3	2	N	1190	2500		y	None	No remediation work

Well Name	API No.	Qtr	Section	Township	Range	Soil Remediation?	Pre-Remediation TPH Concentration (mg/kg)	Cleanup Goal (TPH mg/kg)	Post Remediation TPH Concentration (mg/kg)	Metals Analysis (Y/N)	List of Metals > Concentration Thresholds	WOGCC Comments
TP 12-03	1321129	SWNW	3	3	2	N	161	5500		y	None	necessary, no additional investigation No remediation work necessary, no additional investigation
TP 24-03	1306387	SESW	3	3	2			2500	1505	N		VRP site re-scored, additional investigation completed, site will be excavated
TP 31-03	1320457	NWNE	3	3	2	y	4980					Sundry notice of pit closure on file, original investigation not completed due to access, site investigated in 2011, will be VRP
Blankenship 4-8	1320668	SENE	4	3	2							No remediation work necessary, no additional investigation
TP 41-09	1320875	NENE	9	3	2	y		4000	3700	y	None	No Pre-remediation analytical data included in report, not stated in report
TP 22-10	1320876	SENW	10	3	2	N	201	7000				No remediation work necessary, no additional investigation
TP 44-10	1320879	SESE	10	3	2	y		5500	2920	y	None	excavation completed

Well Name	API No.	Qtr	Section	Township	Range	Soil Remediation?	Pre-Remediation TPH Concentration (mg/kg)	Cleanup Goal (TPH mg/kg)	Post Remediation TPH Concentration (mg/kg)	Metals Analysis (Y/N)	List of Metals > Concentration Thresholds	WOGCC Comments
TP 14-11	1306355	SWSW	11	3	2							~60 yds3, no additional investigation
TP 21-11	1320854	NENW	11	3	2							Sundry notice of pit closure on file, no final report received
TP 21-11	1320854	NENW	11	3	2							Sundry notice of pit closure on file, no final report received
WH Paul Patent 42x- 11	1320442	SENE	11	3	2	N	1869	1000				Closure sundry with lab data on file, denied with request to remove contaminate soil above cleanup goal. No additional information submitted following denied sundry
TP 22-12	1320878	SENE	12	3	2							Sundry notice of pit closure on file, no final report received
TP 42-12	1320443	SENE	12	3	2	y		2500	379	y	None	No Pre-remediation analytical data included in report, not stated in report. 2nd investigation

Well Name	API No.	Qtr Qtr	Section	Township	Range	Soil Remediation?	Pre-Remediation TPH Concentration (mg/kg)	Cleanup Goal (TPH mg/kg)	Post Remediation TPH Concentration (mg/kg)	Metals Analysis (Y/N)	List of Metals > Concentration Thresholds	WOGCC Comments
Ora Wells 14-12	1306357	SWSW	12	3	2	N	273	1000		N		completed no additional work required
TP 13-13	1306341	NWSW	13	3	2	N	16	1000		y	None	2nd investigation completed, site will be excavated
TP 11-14	1320857	NWNW	14	3	2	N	16	4000		y	None	No remediation work necessary, no additional investigation
TP 24-14	1306336	SESW	14	3	2	N	3910	4000		y	None	No remediation work necessary, no additional investigation
TP 31-14	1320456	NWNE	14	3	2	y		2500	ND (<14)	N		site re-scored, WOGCC agrees with 4000 ppm, BLM site
TP 21-15	1320889	NENW	15	3	2	N	401	8500		N		Site previously excavated, no additional work necessary
TP 31-15	1320062	NWNE	15	3	2	y	?	5500	70	y	None	No remediation work necessary, no additional investigation
												Site was excavated, approx 1500 yds3, no additional work required

Well Name	API No.	Qtr	Section	Township	Range	Soil Remediation?	Pre-Remediation TPH Concentration (mg/kg)	Cleanup Goal (TPH mg/kg)	Post Remediation TPH Concentration (mg/kg)	Metals Analysis (Y/N)	List of Metals > Concentration Thresholds	WOGCC Comments
TP 44-15	1320764	SESE	15	3	2	N		5500		y	None	No remediation work necessary, no additional investigation
TP 21-05	1306413	NENW	5	3	3	y	?	7000	327	y	None	Excavation completed, approx. 60 yds3, no additional work required
TP 14-06	1306392	SWSW	12	3	3	y	?	2500	1298	y	None	Approx 120 yds3 excavated, no additional work necessary
Horn 13-10	1321414	NWSE	13	4	2	y	7820	4000	137	N		Sundry notice of pit closure on file, no final report received
Horn 18-4	1321416	NWNW	18	4	3							NA

Pits Enrolled by Encana in VRP

As a result of initial investigation in 2005, Encana sought enrollment of three sites in the VRP in 2005. These sites were Tribal Pavillion 42-11, Tribal Pavillion 14-11, and Tribal Pavillion 24-03. Under the VRP program, Encana conducted site characterization and created Draft Remedial Alternatives Evaluations (RAE) in August, 2010. The work conducted as part of the initial site characterization included collecting shallow groundwater and soil samples from the pit sites. Encana's Draft RAE reports identified the suggested remedial alternative as monitored natural attenuation (MNA). DEQ supplied written comments regarding the Draft RAEs to Encana, and Encana followed up with additional sampling work. EPA submitted comments on the Draft RAEs directly to Encana and copied the Wind River Environmental Quality Commission and the DEQ. As of April 2013, Encana had not submitted revised RAEs for these sites, and did not have a final cleanup Remedy Agreement in place. An RAE had not yet been submitted for the fourth site that was enrolled in the VRP at a later time.

Encana's Draft RAEs for three of the four pits sites contain soil and groundwater sampling data. EPA has received data from the fourth VRP site, Blankenship 4-8, through the workgroup process, but EPA has not received any data collected as part of the VRP site characterization process. Also, as part of EPA's Phase 2 sampling efforts in January 2010 (final report in August 2010), EPA collected three soil samples and three groundwater samples, one from each of the three pit sites enrolled in the VRP at that time.

A summary of the data presented in the Draft RAEs prepared for the three VRP pits can be seen in the table below. Included is the OCSRRS TPH cleanup level for the soil, the highest TPH measurement when excavation was finished, and the average concentrations of various compounds measured from the monitoring well with the highest concentrations at each site. Soil remediation goals for sites undergoing groundwater monitoring through the VRP are set according to OCSRRS.

More detailed data from the Draft RAE from the three pit sites can be seen in Appendix C.

Table 2: Summary of data from Remedial Alternative Evaluations

Pit Location	WOGCC TPH Soil Cleanup Level ¹	Highest Soil TPH	Average Benzene in Water	Average Toluene in Water	Average Ethyl Benzene in Water	Average Total Xylene in Water
Tribal Pavillion 24-3	1,000 mg/kg	3,170 mg/kg	1,121 ug/L	ND	272 ug/L	677 ug/L
Tribal Pavillion 42-11	1,000 mg/kg	273 mg/kg	13.2 ug/L	ND	77.5 ug/L	213.4 ug/L
Tribal Pavillion 14-11	1,000 mg/kg	10,270 mg/kg	444 ug/L	ND	58.1 ug/L	12.8 ug/L

Potential Pits Identified by Local Landowners

The full list of community Identified Areas can be found below with proximity to a sampled groundwater well (PGDW) and notes recorded by the landowner representative on the pits work group (see Table 3). It should be noted that there may be other groundwater within the targeted ranges, but they are not included unless they were sampled by EPA.

¹ It is understood that soil clean up levels at the VRP sites are still established using OCSRRS. As the contaminated soil is the source of the groundwater contamination at the these sites, there should be an evaluation regarding necessary soil cleanup goals to ensure any selected groundwater remedy will meet VRP groundwater remediation standards and be protective.

Table 3: Community Identified Areas

<u>CIA Number</u>	<u>Well No.</u>	<u>W/in 500 ft of PGDW</u>	<u>W/in 1000 ft of PGDW</u>	<u>W/in 1500 ft of PGDW</u>	<u>Summary of Notes Provided</u>
1	21-9	No	PGDW42	PGDW42	"It was not uncommon to be flooded with produced water and other fluids"
2	Lloyd#1	No	No	PGDW30	"told by some of the old timers that this pit was always full of fluid" "some of the current production equipment for the new well is sitting partially on top of this pit"
3	33X-10	PGDW44 - stock	PGDW44 - stock	PGDW44 - stock	"33X-10 P&A well original depth 19235'" "pit is visible in aerial photos" "growth of crops is very stunted and this area is irrigated 2-5x per year"
4	15-21X	No	No	No	"you can see where pit has been reclaimed" "lack of plant growth" "large pit just south of the well was used for several years"
5	11-10	No	No	No	"this location is close to 33X-10 at time it was drilled" "large concrete structure is still there where rig was erected" "may be testimony about this location from Dr. Dollhoff"
6	41-9	PGDW43 - stock	PGDW43 - stock	PGDW43 - stock	"While pit was excavated, the hole filled approx. half full of water and smelled very strong of hydrocarbons" "very close to irrigation canal 30'-50"
7	31-10	No	PGDW30	PGDW30	"pit is on location in field" "liner is sticking up through ground" "used for drilling and completion"
8	43-10	PGDW23	PGDW23	PGDW23	"this was a lined drilling pit. pit has been severely damaged. Oily stains leach to surface. Cross section of pit is visible on north side"
9	41-15	No	No	No	"possible old lined drill pit on this location"
10	43-10B	PGDW23	PGDW23	PGDW23	"cuttings buried on location in unlined pit. Pit located on east side of

<u>CIA</u> <u>Number</u>	<u>Well No.</u>	<u>W/in 500</u> <u>ft of</u> <u>PGDW</u>	<u>W/in 1000 ft</u> <u>of PGDW</u>	<u>W/in 1500 ft</u> <u>of PGDW</u>	<u>Summary of Notes Provided</u>
					well head"
11	33-10B	No	PGDW44, PGDW23	PGDW44, PGDW23	"cuttings buried on location in unlined pit. Pit located south of well head"
12	The Bowl (33X-10)	No	No	PGDW44	"not a pit" "a natural bowl area used to dump drilling mud and cuttings in the past" "possibly started with 33X-10" "soil smells of hydrocarbons when dug into"
13	12-13	PGDW32	PGDW32	PGDW32	"on Joe Dennis property" "old well that was P&Ad around 200 or 2001" "know there was an old pit here, I don't know much history about it"
14	33-10 or 33-10W	No	PGDW44	PGDW44, PGDW23	"cuttings buried on location in unlined pit"
15	23-10C	No	No	PGDW47	"cutting buried on location in unlined pit" "I believe that pit is east of well head"
16	23-10B	No	No	No	"cuttings buried on location in unlined pit"
17	Pond (41-10B)	No	PGDW30	PGDW30	"pit is in Zoe Randall's field" "not sure of exact location, but believe that it may be on east edge of field where there is currently a depression"
18	14-1	No	No	No	"this is one of the older wells" "has old drill/production pit on it" "not sure of exact location"
19	Coolidge Well 1-4	No	No	No	"one of the older wells in area" "on Tribal farm ground" "there is an old pit there"
20	44-15	No	PGDW48	PGDW48	"location is still producing and is located on the Foxworthy's place"

<u>CIA</u> <u>Number</u>	<u>Well No.</u>	<u>W/in 500</u> <u>ft of</u> <u>PGDW</u>	<u>W/in 1000 ft</u> <u>of PGDW</u>	<u>W/in 1500 ft</u> <u>of PGDW</u>	<u>Summary of Notes Provided</u>
21	Tribal 21	No	PGDW48	PGDW48	just south of No. 20 "it is buried" "no longer a location there" "Louis Meeks is familiar with the details of this location"
22	Kerr McGee	No	No	No	"Old Kerr McGee exploratory well" "there is a buried pit but well is P&A complete" "Lease #14-20-0258-2964"
23	21-15	No	No	PGDW47	"has pit" "not known if part of Encana's cleanup program"
24	24X-14	No	No	No	"older well" "has a pit" "not known if part of Encana's cleanup program"
25	31X-14	No	No	No	"older well" "has a pit" "not known if part of Encana's cleanup program"
26	11-14	No	No	No	"drilled 1980" "has pit" "WOGCC website states that it had been part of pit closure 11/9/2007"
27	14-12	No	PGDW22	PGDW22	"ORA wells" "Tribal Pav 14-12" "had pit cleanup 3/28/08" "sundries on WOGCC website"
28	22-12	No	PGDW20	PGDW20	"was part of pit closure" "partial records on WOGCC website"
29	Muddy Ridge	No	No	No	"on the North side of Muddy Ridge" "A lot of old pits here" "Local farmer showed us some of the pits that were supposed to have been cleaned up and had oil stains seeping up out of the area"
30	33-11X	No	No	No	This is one of the pits EPA sampled – "cuttings buried in pit that is now stockyard for hay" "about 300 ft north of the VRP pit"
31	31-9	No	PGDW42	PGDW42, PGDW43	"cuttings buried here" "well drilled about 2000-2001" "remember that groundwater is shallow here"
32	13-03W	PGDW41	PGDW41	PGDW41	"large pit here" "behind the former house of Bill Garland" "pit can be seen on Google Earth"

After touring the Community Identified Areas, eight locations identified by the community were removed from future consideration due to the conclusion that no pit was located at the site, as described in Table 4.

Table 4: Community Identified Areas Removed from Consideration

<u>CIA Location</u>	<u>Well Location</u>	<u>Rationale</u>
5	Pavillion 11-10	No evidence that well existed; there is only a pad here.
7	Pavillion 31-10	APD states that no pits will be constructed; Liner found on site used to stabilize raised pad within field, but not used for pit.
14	Tribal 33-10, 33-10W	Records indicate cuttings transported off-site.
17	Pavillion Fee 41-10B	Semi circular depression. No evidence found that this is an actual pit. Nearest production well is 600 feet away. Unlikely that pit was located this far from well.
21	Tribal 1-22 (Tribal 1)	Walked site and did not see any evidence of historic pit
22	Tribal Unit 1	Walked site and did not see any evidence of historic pit
29	Muddy Ridge	Remove because Muddy Ridge is outside Pavillion Field
32	Pavillion Fee 13-03W	Closed loop drilling, cuttings taken off site.

After reviewing data provided by Encana of cuttings TPH analytical results, the workgroup agreed that the cuttings pits present a lower concern, due to TPH concentrations, in general, being less than TPH concentrations in other types of pits.

The workgroup agreed on the following order of priority for consideration of community identified pits based on likelihood of contaminants being present:

1. Reserve pits
2. Production pits
3. Cuttings pits

Encana developed work plans and initiated work as described below to conduct environmental characterization at 6 community identified pit sites.

1. Tribal Pavillion 21-9 (landowner identified #1) – Encana planned to fix the marker identifying the well as plugged and abandoned, conduct limited soil sampling to evaluate hydrocarbons and SAR, collect background sample for comparison, and if boring encountered groundwater at 15 ft or less, sample groundwater.

2. WE Lloyd #1 (landowner identified #2) – Encana planned to conduct limited soil sampling in suspected pit area for hydrocarbons and SAR, collect background for comparison, and if boring encountered groundwater at 15 ft or less, sample groundwater
3. Tribal Pavillion 12-13 (landowner identified #13) - Encana planned to conduct limited soil sampling in suspected pit area for hydrocarbons (SAR not an apparent issue as grass growing in the area), collect background for comparison, and if boring encountered groundwater at 15 ft or less, sample groundwater
4. Pavillion Fee (Ora Wells) 14-12 (landowner identified #27 and previously investigated) – Additional excavation work was required by WOGCC based on a Sundry Notice dated August 11, 2009.
5. Tribal Pavillion 22-12 (landowner identified #28 and previously investigated) – Encana planned to conduct limited soil sampling in suspected pit area for hydrocarbons, and if boring encountered groundwater at 15 ft or less, sample groundwater.
6. Pavillion Fee 31-9 – (landowner identified #31) – This location appeared to only have had cuttings buried, but was proposed as the one test location to confirm the low or non-existent hazard presented by cuttings. Encana planned to collect samples for hydrocarbons and SAR.

Two of these sites (14-12 and 22-12) were chosen because WOGCC had records indicating cleanup goals had not been met. Three of these sites (21-9, WE Lloyd #1, and 12-13) were chosen for further evaluation as there were indications that pits containing hydrocarbon contaminated soil were not previously evaluated. One site (31-9) was chosen as a cuttings pit site to evaluate.

During these site activities, Encana also completed an investigation of the Blankenship 4-8 pit site. This is a site that was not evaluated previously due to access issues with the landowner. Additional assessment work was completed at Tribal Pavillion 31X-3 and Tribal Pavillion 42X-12 during these site activities as well. These sites had previously been investigated by Encana, but were not community identified areas. After reviewing WOGCC records, it was determined that these two sites potentially needed further remediation since records indicated TPH concentrations remaining at the sites were higher than the cleanup levels calculated using OCSRRS. Data collected during these characterization efforts is summarized in Table 5.

Encana committed to the following non-invasive actions at community identified areas. It is uncertain if these activities have been completed.

1. Pavillion Fee 33X-11 (landowner identified #30) - Encana was to continue sampling a monitoring well that appears to be near the pit location (part of current VRP site)
2. Tribal Pavillion 41-9 (landowner identified #6 and previously investigated) – Encana was to monitor the adjacent irrigation ditch for visible sheen on a semi-monthly basis during irrigation season, to report back to the workgroup.
3. Pavillion Fee 33-11 (landowner identified #30) – Cutting pit was not on drilling location, but was actually north of the rock outcropping at the 42X-11 VRP location. The cutting pit of concern is located adjacent to MW-5 monitoring well for the VRP location. No

hydrocarbons had been detected to date at that location. Encana was to continue monitoring as part of VRP.

The scope of the field work for all of the additional Encana investigations varied from site to site, but, in general, most sites had multiple soil borings. A soil sample from each boring was sent for DRO and GRO analysis using analytical Method 8015. Using a FID/PID, the contractor sent a soil sample with the highest FID/PID screening value to an analytical lab to be analyzed for SVOCs by Method 8270C, BTEX by Method 8260B, and DRO and GRO by Method 8015. There were 53 analytes included in the SVOC analyses, and four analytes in the BTEX analysis. A brief summary of the data from seven community identified sites Encana completed field work on is shown in Table 5. More detailed data reports are presented as Appendix D.

Table 5: Summary of Data from Additional Encana Field Investigations

Location	Highest Soil GRO	Highest Soil DRO	Highest Soil COCs (SVOCs or BTEX) ^{2 3 4}	Groundwater GRO	Groundwater DRO	Groundwater COCs (SVOCs or BTEX)
14-12 (Community Identified, previously Investigated)	340 mg/kg	1500 mg/kg	ND (Benzene DL = 0.1 mg/kg)	<100 ug/L	1.2 mg/L	ND (Naphthalene <0.001 mg/L, Benzene <0.001 mg/L)
21-9	18 mg/kg	18000 mg/kg	ND (Benzene DL= 0.05 mg/kg, Naphthalene DL = 1.6 mg/kg)	N/A – didn't encounter	N/A – didn't encounter	N/A – didn't encounter
W.E. Lloyd #1	<500 ug/kg	390 mg/kg	Naphthalene 0.22 mg/kg (Benzene DL = 0.05 mg/kg)	<100 ug/L	0.32 mg/L	ND (Naphthalene <0.001 mg/L, Benzene <0.001 mg/L)
12-13	<0.50 mg/kg	<4.0 mg/kg	ND (Benzene DL= 0.005 mg/kg, Naphthalene DL = 0.033 mg/kg)	N/A – didn't encounter	N/A – didn't encounter	N/A – didn't encounter

² For Benzene, the EPA Risk Based Soil Screening Level is 0.0002 mg/kg and the WDEQ migration to groundwater cleanup concentration is 0.00023 mg/kg.

³ For Naphthalene, the EPA Risk Based Soil Screening Level is 0.00047 mg/kg and the WDEQ Migration to Groundwater Cleanup Concentration is 0.00055 mg/kg.

⁴ For Pyrene, the EPA Risk Based Soil Screening Level is 0.95 mg/kg and the WDEQ Migration to Groundwater Cleanup Concentration is 150 mg/kg.

Location	Highest Soil GRO	Highest Soil DRO	Highest Soil COCs (SVOCs or BTEX) ^{2 3 4}	Groundwater GRO	Groundwater DRO	Groundwater COCs (SVOCs or BTEX)
22-12 (Community Identified and Previously Investigated)	<0.5 mg/kg	41 mg/kg	Pyrene = 0.41 mg/kg (Naphthalene DL = 0.33 mg/kg)	<0.10 mg/L	2.2 mg/L	ND (Naphthalene < 0.001 mg/L, Benzene <0.001 mg/L)
31-9 (cuttings only)	<0.5 mg/kg	< 4.0 mg/kg	ND (Naphthalene DL = 0.033 mg/kg, Benzene not analyzed)	N/A – didn't encounter	N/A – didn't encounter	N/A – didn't encounter
Blankenship Fee 4-8	<0.5 mg/kg	< 4.0 mg/kg	Naphthalene = 5.3 mg/kg (Benzene not analyzed)	5.2 mg/L (water table at 2 ft bgs)	13 mg/L	Benzene – 0.110 mg/L, Naphthalene – 0.072 mg/L

These analytical results were compared to EPA's Regional Soil Screening Levels (RSLs) for the protection of groundwater, though in many cases a comparison was not possible as detection levels for analytes were above the RSL. For benzene and naphthalene, among other compounds, the analytic detection limit is higher than both the EPA RSL and the DEQ soil cleanup target for migration to groundwater; hence these data are unable to demonstrate whether the SSL or DEQ target was met or exceeded.

These soil RSLs were developed by EPA using standard equations and exposure assumptions. Soil RSLs are considered by the Agency to be protective over a lifetime of exposure. Care should be taken when comparing contaminant concentrations to the RSLs where multiple chemical exposures may contribute to risks above targets. These concentrations are used as screening concentrations to help identify sites, or areas of sites, that require further investigation. Contaminant concentrations above the RSLs do not automatically trigger a response action, but suggest further investigation may be warranted.

The purpose of the following table is to display how the detection limits of the specific analytes for the pit soil samples compare to the EPA RSLs. Since this is a comparison of specific analytes, it does not include DRO and GRO (which do not have EPA RSLs).

Table 6: Comparison between Analyte Detection Limits and EPA Soil Screening Levels

Gas Well ID Associated with Pit	Analytes without soil RSLs	Analytes with analytical method detection limits/concentrations lower than soil RSLs	Analytes with analytical method detection limits higher than soil RSLs	Analytes with soil concentrations higher than soil RSLs
<i>Community Identified Areas</i>				
21-9	12	8	37	0
W.E. Lloyd #1	12	16	28	1 (Naphthalene)
12-13	12	16	29	0
22-12	12	11	34	0
31-9	12	14	27	0
<i>Previously Evaluated Areas</i>				
Blankenship 4-8	12	12	28	1 (Naphthalene)
31X-3	12	16	28	1 (Naphthalene)
42X-12	12	16	29	0
14-12	0	2	2	0

It should be noted that soil samples for 14-12 were only analyzed for BTEX and TPH.

As can be seen, many contaminants have analytical detection limits higher than the RSLs. As a result, it cannot be determined whether these contaminants are present above the screening level; thus, a meaningful conclusion cannot be drawn regarding ongoing risk associated with the presence or concentration of these contaminants at the pit sites requested to be evaluated by the community.

EPA Data Collected as part of Phase 2 Sampling Event

In January 2010, EPA collected three subsurface soil samples and three groundwater samples from the three pits that were enrolled in the VRP at the time. After reviewing sampling data provided by Encana, EPA sampled one well at each site. The well that was selected was characterized by previous sampling as the most contaminated well. A soil boring from each pit location was taken using a Geoprobe. PGMW01 was collected from MW1 from the VRP site associated with well 24-3. PGMW02 was collected from MW6 from the VRP site associated

with well 14-11. PGMW03 was collected from MW4 from the VRP site associated with well 42X-11.

The samples were analyzed by an EPA Contract Laboratory Program Lab for VOCs, SVOCs, Pesticides, PCBs, and Metals. The samples were analyzed by EPA's Region 8 Laboratory for VOCs, SVOCs, DRO, GRO, Water Chemistry Parameters, and a set of Tentatively Identified Compounds, which were preliminarily identified in a previous round of EPA sampling of domestic wells in the area. A separate contracted lab analyzed the samples for GRO, DRO, TPH, and Total Extractable Hydrocarbons (TEH) using Method SW846 8015B, as well as iron reducing and sulfate reducing bacteria by Method IRB-BART, and heterotrophic plate counts by Method A9215E.

Groundwater contamination was found to be present, including elevated levels of phenol, 2, 4-dimethylphenol, 2-methylphenol, 4-methylphenol, 2-methylnaphthalene, naphthalene, 1,3,5-trimethylbenzene, adamantane, 1,3-dimethyl adamantane, benzene, toluene, ethyl benzene, xylene, isopropyl benzene, cyclohexane, dissolved methane, tert-butyl benzene, DRO, GRO, and barium. Iron reducing and sulfate reducing bacteria were present in elevated counts in all three wells as compared to drinking water wells in the area. This is not unusual given that the highest hydrocarbon levels were found in these wells, which would promote higher populations of these bacteria. Data from EPA's samples are presented in EPA's Phase 2 Analytical Results report located in Appendix E.

These elevated concentrations of contaminants in groundwater identify pits as a potential source of hazardous constituents. Benzene in particular was of concern, due to the fact that the concentrations were as high as 390 ug/L, which is 78 times above the drinking water MCL of 5 ug/L.

Data Limitations

DRO/GRO/TPH Analysis

Diesel Range Organics, Gasoline Range Organics, and Total Petroleum Hydrocarbons, using EPA method 8015, are designed to determine the total amount of hydrocarbon within the ranges set by the specific analytical method. Using this method, it is typically not possible to identify the specific compounds that are present in the sample. One could, presumably, determine a class of compounds that are present by looking at the elution times present in a chromatogram of the sample, and comparisons could be made to determine if similar ranges of compounds are present in various samples. However, other methods would need to be used to identify concentrations for contaminants of concern.

Detection Limits

As discussed previously, many of the reported analytical detection limits are higher than the comparison values used to assess risk. There may be limitations of the method or instrument that prevent the analyst from lowering the detection limit, or it may be possible to adjust the method or utilize a different method to achieve the detection limit necessary to allow meaningful comparison with risk-based screening levels. Additionally, if a sample needs to be diluted, the

detection limit is raised proportionally to the dilution amount. This limitation makes it challenging to determine the risk posed by soil or groundwater that is represented by the sample.

Commentary regarding existing cleanup

Cleanup of contaminated soil

The WOGCC Pit Closure Guidance, alone, presents difficulties in regard to source and risk characterization of contaminated soil. TPH is an insufficiently specific measure to support characterization of toxicity and environmental risk of a particular source, though it can serve as a measure of contamination. Potential contaminants within and outside the range of TPH may be hazardous at levels above risk screening levels, but would not be known when analyzing solely for TPH. Using TPH alone as an analytical measurement and cleanup goal might not be protective, as specific contaminant concentrations are not known at each site. Sampling for site specific contaminants of concern should be conducted to better characterize potential waste sources. Currently, analysis for specific analytes occurs at VRP sites, including sites related to energy exploration and production with known groundwater contamination above State standards, as evidenced in the four VRP sites currently in the Pavillion gas field. EPA recommends this practice be considered for application to energy exploration and production sites in general due to the presence of constituents of concern at these sites.

Additionally, the WOGCC guidance procedures are not able to determine if use of a pit resulted in contamination to underlying groundwater. TPH is too broad a measure to determine whether or not groundwater resources are potentially at risk from various hazardous constituents both included within and outside the range of hydrocarbons measured using TPH analysis. The fact that no groundwater was encountered during testing and removal of contaminated soil does not confirm that groundwater contamination did not occur at the various pit sites, and flood irrigation practices may dramatically influence groundwater levels and movement on a seasonal basis. Installing at least one groundwater monitoring well and sampling for COCs at every pit location where contaminated soils were detected would better determine if known source areas have contaminated groundwater.

Cleanup of contaminated groundwater

In general, among other things discussed in EPA's December 3, 2010 letter to Encana, which is included in Appendix F, a remedy selection process should be used to determine the best approach for reaching cleanup goals. This process includes evaluation of cost, time for groundwater to reach cleanup goals, risks presented by each remedy and the practicability of the remedy. This evaluation assumes that more than one remedy is available to be compared. The first RAE drafts provided by Encana presumed monitored natural attenuation (MNA) was the optimal remedy, without discussing or evaluating other remedial options or providing sufficient monitoring data on contaminant plume boundaries and concentration profiles to support the selection of MNA as an appropriate and effective remedy for these sites. Future decisions on site remediation should include discussion on the various available remedies with regard to cost, practicability, risks, and the time necessary to reach the cleanup goals.

Further groundwater contaminant characterization is necessary to define the source and characterize the contaminant plume and the groundwater flow system. The intent of this follow-up work should be to lower the uncertainty regarding the location and geometry of the contaminant plume to support the remedy selection. Although these suggestions are focused

on the four sites enrolled in the VRP, they merit consideration for other pit sites. EPA recommends that additional data be developed to address the following:

1. There is uncertainty with respect to what groundwater is collected from the screened intervals of the wells installed as part of the VRP. The installed monitoring wells, which are approximately 30 ft. or shallower, are likely screened in the colluvial groundwater or a weathered bedrock zone above the Wind River Formation. It is unknown whether or not contamination which is known to be in these "shallow" aquifers has migrated to the Wind River Formation, or the extent and depth of that migration within the aquifer. Installing a sufficient number of wells at each location screened at multiple depths in the Wind River Formation below the water table would enable the vertical and horizontal extent of aquifer contamination to be determined.

As was mentioned in the December 3, 2010 letter from EPA to Encana, MNA determinations for all pit areas should at a minimum include:

- a. at least three wells located within the plume along the axis of the plume;
 - b. one uncontaminated up-gradient well;
 - c. enough wells cross-gradient and down-gradient of the plume to support development of plume isoconcentration plots or well concentration vs. time plots including seasonal groundwater flow variations;
 - d. additional monitoring for geochemical parameters newer sources including chloride, and dissolved methane and light gases;
 - e. additional monitoring for petroleum hydrocarbon natural attenuation primary geochemical indicators, dissolved O_2 , redox potential, pH, specific conductivity, and temperature and secondary geochemical indicators including SO_4^{2-} , NO_3^- , Fe^{+2} , Mn^{+2} , CH_4 and alkalinity; and
 - f. additional monitoring for LNAPLs.
2. Water table elevation contour maps should be prepared for each of the pit locations for different times during the year to account for seasonal variation, including when irrigation water is applied as well as base flow. The annual application of irrigation water likely results in significant temporal changes in the water table surface which can result in changes in groundwater flow direction and velocity over the annual hydrograph. These perturbations will have a significant effect on the migration of dissolved contaminants and the ultimate geometry of the contaminant plume.
 3. There should be a discussion regarding the attenuation processes that will be relied upon to remediate the contaminants present at the specific site. Follow-up activities in 2011 did include collection of some indicator data that is necessary to evaluate the effectiveness of natural attenuation at the sites. There should be discussions regarding the constraints or limitations of natural attenuation processes at these sites.
 4. It is understood that soil clean up levels at the VRP sites are still established using OCSRRS. As the contaminated soil is the source of the groundwater contamination at

the these sites, there should be an evaluation regarding necessary soil cleanup goals to ensure any selected groundwater remedy will continue to be protective.

Specifically regarding the VRP site associated with well 14-11:

5. Groundwater velocity estimates likely need to be refined. The groundwater velocity was reported to be 0.01 to 0.03 feet per year for the WH Paul patent 42X-11 site. The groundwater plume associated with this site extends at least 375 feet in a down gradient direction. At a velocity of 0.03 feet per year – more than 12,000 years would be required for groundwater from the pit to flow 375 feet. One of the following would appear to be the case: (1) the velocity estimates are wrong; (2) there are preferential flow paths which have much higher velocities; or (3) there are additional sources of COCs other than the pit contributing to this plume.

Without the information described above, it becomes difficult to define the nature and extent of contamination at the pit sites. Without additional characterization, it is difficult to determine the down-gradient extent of contaminant migration that may have potential to impact domestic water wells in the area, and the potential exposure risks associated with those down-gradient contaminants. In addition, without this information it is difficult to assess whether and when cleanup targets in groundwater will be met along the plume gradient, which is an important consideration in the selection of MNA as an appropriate remedy. The two cleanup processes (WOGCC guidance and VRP process) might benefit from better understanding of how soil cleanup levels derived from the OSSCRS may impact groundwater, so as to refine and integrate the two programs.

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APPENDIX A – DEQ VRP Cleanup Levels

APPENDIX B – EPA Regional Screening Levels

APPENDIX C – Encana VRP Remedial Alternatives Evaluations

APPENDIX D – Encana Pit Investigation Reports

APPENDIX E – EPA Phase 2 Analytical Results Report

APPENDIX F – December 2010 letter from EPA to Encana regarding Remedial Alternative Evaluations

